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Effect of Quantitative Easing on the Indian Economy: A Dynamic Stochastic General Equilibrium Perspective*

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Abstract

The effect of external Quantitative Easing (QE) on a small open economy such as India is analyzed using a dynamic stochastic general equilibrium (DSGE) model. The modelling is motivated by some broad empirical regularities of the Indian economy during the pre and post QE periods. QE is modelled as a negative foreign interest rate shock with a mean reverting pattern. The mean reversion reflects the phasing out of the QE operation. In addition, we analyze the "news" effect of the tapering out phase of QE. Our model has standard frictions which include limited asset market participation of agents, home bias in consumption and nominal frictions in terms of staggered price settings. Monetary policy is modelled by the forward looking inflation targeting Taylor rule. The model explores a novel transmission channel of QE via the terms of trade measured by the ratio of import to export prices. We show that the *impact* and *news* effects of QE work through the terms of trade via the uncovered interest parity condition. Our model reproduces two prominent features of the Indian data: (i) initial decline of the terms of trade followed by a sharp reversal, and (ii) divergent behaviour of foreign and domestic interest rates. The model is broadly consistent with other empirical regularities including a deflationary spell in the Indian economy after 2012.

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1 Introduction

The world economy went through major upheavals since the outbreak of the global financial crisis (2007-09). Given the scale and depth of this crisis experienced by different parts of the world, unprecedented policy interventions were triggered by the central banks (CB) of advanced countries led by the US Federal Reserve. Due to severe liquidity shortages faced by the banks, the US Federal Reserve Board resorted to the unconventional measures to inject liquidity involving non-traditional asset purchases which is widely known as Quantitative Easing (QE hereafter). These assets largely consisted of agency debt, mortgage-backed securities and Treasury securities. The end result of this operation was a sharp decline in the nominal interest rate in the US nearly hitting the zero lower bound.

In the US, the QE was launched in three phases. Following the collapse of Lehman Brothers in September 2008, during the first phase large-scale asset purchases (LSAP) of agency debt, mortgage-backed securities and Treasury securities were undertaken. The second phase which started from October 2010 experienced massive purchases of Treasury securities. The third phase of QE that started from September 2011 involved the sterilized acquisition of long term bonds financed by selling some its short term bonds accompanied by LSAP.¹ The trend of QE was interrupted in May 2013 when the Fed signaled its intention to unwind its unconventional monetary policy. On May 22, 2013, Chairman Ben Bernanke first spoke of the possibility of the Fed tapering off its security purchases. The US quantitative easing is now ending while the European Central Bank has launched a new programme of quantitative easing since 22 January, 2015.

The impacts of quantitative easing on emerging market economies (EME) have become increasingly controversial in recent years. Mishra et al.(2014) argue that QE set off a global search for yield by investors herding into the emerging markets which contributed to mispricing of domestic assets. An influential strand of literature views that the phasing out of QE would be detrimental for the EMEs and could lead to major economic downturn (Rajan, 2014, Basu et al., 2014, Eichen-green and Gupta, 2014) due to macroeconomic imbalances and weak financial sector. Emerging

¹By the end of phase 1 of QE, the Fed had injected \$2.1 trillion into the US economy. During November 2010, the Fed started the second round with purchase of \$600 billion worth of Treasury securities along with an added investment of \$250-300 billion in treasuries from the profits of the previous investments. In phase 3, the initial budget was \$40 billion/month, which got raised to \$85 billion by December 2012. *Source:* www.macroeconomicanalysis.com.

economies are concerned about its negative spillover effects on their capital flows, exchange rates, and asset prices. Raghuram Rajan, the governor of the Reserve Bank of India argued that this phasing out may give rise to unnecessary volatility in the global financial markets and could lead to harmful spillover effects (Rajan, 2014). While it is generally accepted in the literature that QE was effective in lowering US long-term yield rates and stimulating economic activity (Lavigne, et al., 2014), evidence on their international spillover effects are rather sparse. There is a strand of empirical literature which has investigated the spillover effects using mostly the event study methodology (Mishra, et al., 2014; Basu, et al, 2014, Rai and Suchanek, 2014), counterfactual experiments (Barosso, et al., 2013), and VAR and VECM approaches (Tillmann, 2014).

Indian economy witnessed many changes during the QE period although it is not clear whether these changes were necessarily the consequences of QE. Figure 1 provides a snapshot of the economy covering the pre and post QE periods. With the onset of QE, real GDP growth rate rose and then decelerated, the exchange rate sharply depreciated against key currency such as US dollar. CPI inflation rate also showed a spurt followed by a subsequent decline. On the external front the net export steadily declined accompanied by a decrease in the terms of trade defined as the ratio of import to export prices until the end of 2011. The terms of trade abruptly reversed its pattern since 2012 with a spike. This was followed by an upward swing in net export which continued until 2013. This is also the time when the QE taper talk started gathering momentum.²

²Data for all the relevant macroeconomic variables came from Datastream. All series are available at a quarterly frequency except the terms of trade. The annual series for terms trade were interpolated to obtain the quarterly series. Nominal series were converted to real using the CPI deflator.

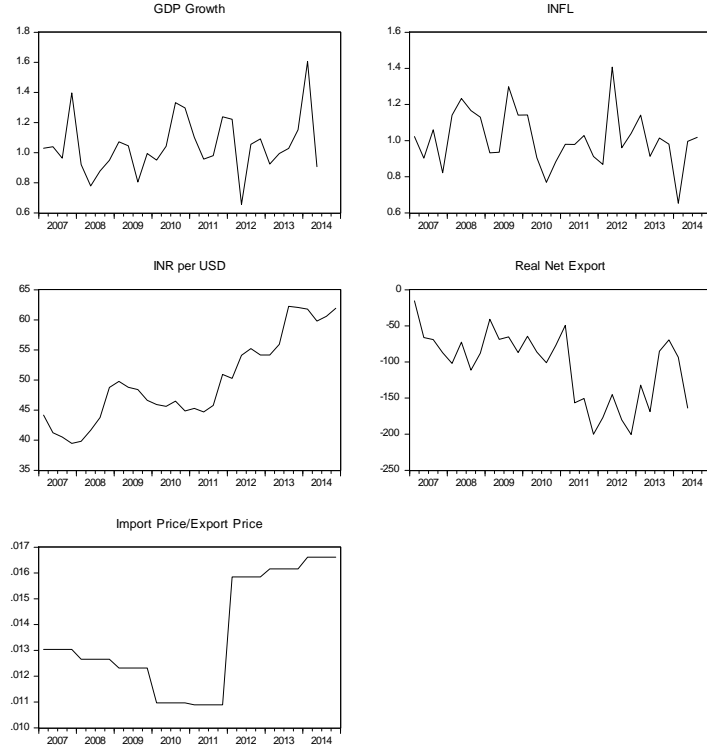


Figure 1: Indian Economy during the QE period

On the monetary policy front, some puzzling developments occurred. With the onset of QE, both the US Federal Funds rate and Indian Repo rate went down and moved in unison. While the US rate approached the zero lower bound, the Indian Repo rate started rising from year 2010. These divergent paths of interest rates seem puzzling. One may argue that the Reserve Bank of India (RBI) possibly changed its policy priority. Initially it was following the interest rate paths of the major players such as the Federal Reserve and the ECB, and subsequently the policy became more inward by focusing on inflation targeting. While this could be a plausible explanation for the divergent paths of Repo and Federal Funds rates, interestingly this has not received much attention in the policy frontier.

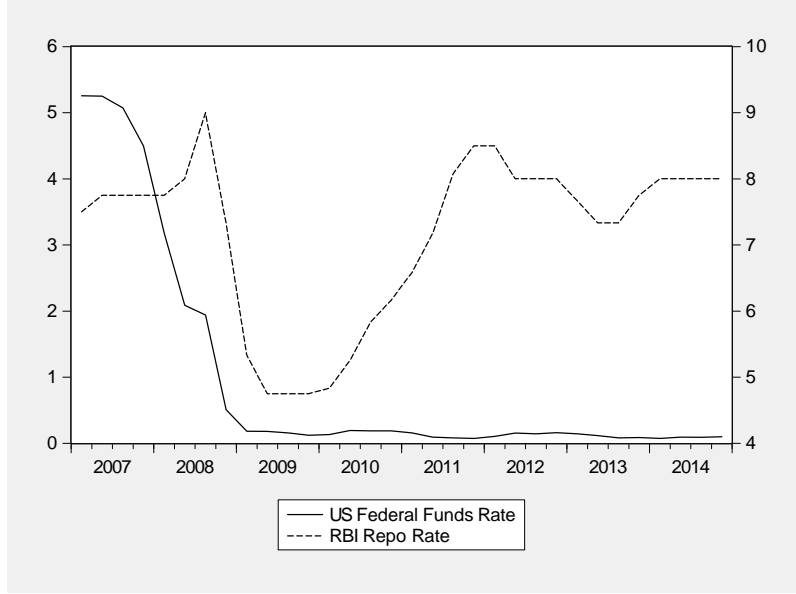


Figure 2: Indian Repo Rate and US Federal Funds Rate

Although, the current policy debates are pivoting around the effects of QE and its phasing out on the EMEs, hardly any effort is made in the literature to model the same in a dynamic stochastic general equilibrium (DSGE) framework with an open economy perspective. Our paper precisely aims to do this. In this paper, we set up a small open economy DSGE model with an aim to understand the effect of QE on an emerging market economy like India. QE is modeled as a negative shock to the foreign interest rate which shows a mean reverting pattern. The mean reversion is the tapering out phase of QE. Bulk of the existing literature has provided explanations for the effect of QE through the movement of capital flow across the border and via the macroprudential linkages with emphasis on banking frictions. In contrast, we argue that the transmission channel of such QE shock on the EME works primarily through the terms of trade. The terms of trade channel is motivated by the observed behaviour of terms of trade in India during the QE period as seen in Figure 1. It declined with the advent of QE and then it showed a major reversal from late 2012. Our model predicts that the terms of trade would decline following a negative foreign interest rate shock accompanied by a home currency depreciation. When the market receives early taper news, it will reverse its pattern which would also give rise to some deflationary effects on the home economy as seen broadly in the Indian data.

Our model builds on Basu and Thoenissen (2011) where the home country is linked to the rest of the world through tradeable intermediate goods. The model has standard frictions typical of small open economy like India which include: (i) aggregate habit persistence as in (Abel, 1990), (ii) investment adjustment cost as in Christiano et al. (2005), (iii) home bias in consumption and investment as in (Backus et al., 1994), (iv) imperfect capital mobility in terms of transaction cost of foreign asset holding (as in Benigno, 2009), and (v) nominal frictions in terms of staggered price setting as in Calvo (1983), (vi) financial frictions in terms of the existence of "rule of thumb" consumers. Monetary policy is modelled by the forward looking inflation targeting Taylor rule. We incorporate both domestic and foreign shocks in our model. The former includes total factor productivity and investment specific technology, monetary policy and fiscal policy shocks. The foreign interest rate shock is the only external shock in our model which we perceive as a QE shock.

The basic transmission channel of a QE shock works as follows in our model. A lower foreign interest rate makes the home currency depreciate via the uncovered interest parity condition. This is very much in line with the stylized facts reported in Figure 1. Since the home country sets its export price in foreign currency due to the widespread use of pricing-to-market, home intermediate goods producers experience an increase in its cash flow and find it profitable to supply more exportables in the international market. This increase in intermediate goods production drives up the real marginal cost. Since the home intermediate goods producers use a staggered pricing rule, this rise in marginal cost translates into a higher relative price of home produced intermediate goods with respect to CPI. This immediately results in a lower terms of trade via the composite CPI which is a weighted average of prices of home and foreign produced intermediate goods. This favourable tilt in the terms of trade lowers our net export as seen in Figure 1. Higher real marginal cost also heightens domestic inflation to which the home Central Bank responds positively by raising the interest rate via a Taylor rule. This explains why the home interest rate moves in the opposite direction of the foreign rate as seen in Figure 2. A higher real marginal cost drives up the real wage and rental price of capital which promote labour supply and investment.

We also analyze the macroeconomic effects of a taper talk of QE. The QE taper is modelled as a "news" effect of a future rise in foreign interest rate. Such a "news" is perceived by the market as

a future appreciation of the home currency which lowers the expected relative price of exportables because the price of exportable is set in foreign currency. This encourages the home producers initially cut back export giving rise to a large drop in net export. As home producers lower the production of exportable, it drives down the real marginal cost which feeds into a *deflationary* spell via the home price setting function. The CB cuts interest rate to respond to low inflation which makes the home currency appreciation materialize as broadly seen in Figure 1 after 2013. The terms of trade first declines and then rises as the QE taper materializes reflecting the observed pattern.

The impulse responses of a QE shock and also a news shock of QE tapering based on our stylized DSGE model accords reasonably well with the key macroeconomic data: GDP rises, inflation gathers momentum and in response to this the CB raises the interest rate. This explains why the home policy rate and foreign policy rate move in opposite directions. Due to a favourable terms of trade effect, the current account deteriorates which means net capital outflow. Then a subsequent taper talk of QE reverses the courses of the terms of trade, inflation, the net export which are broadly consistent with the post QE experience in India.

The plan of the paper is as follows. In the following section, we lay out the model. Section 3 reports the model simulation results. Section 4 concludes.

2 The model

The model environment is similar to Basu and Thoenissen (2011), and Banerjee and Basu (2014). Consider a small open economy with incomplete financial markets. Each country produces one tradable intermediate good that is used in the home and foreign consumption and investment goods baskets. Similar specification of consumption and investment goods is found in Heathcote and Perri (2002), Backus et al. (1994) and Thoenissen (2008), Basu and Thoenissen (2012). To address the business cycle features of the emerging market or developing economy like India, this model incorporates various frictions and shocks, as proposed in Kollmann (2002), Smets and Wouters (2003), Christiano, Eichenbaum and Evans (2005). We consider frictions in the form of external habit formation in consumption, investment adjustment costs, transaction cost of foreign bond holding and staggered price setting of the intermediate goods producing firms. The model dynamics

are driven by five shocks, namely, total factor productivity (TFP), investment specific technology (IST), monetary and fiscal policy shocks, foreign interest rate shocks.

2.1 Description of the Economy

Representative household owns the physical capital stock, supplies labour and rents capital to the intermediate goods firms. At date t , household receives its proceeds from wage income, rental income, profit from the ownership of firms and interest income from domestic and foreign bond holding. The household uses its income at date t by consuming final consumption goods, investing in physical capital, buying new bonds (domestic as well as foreign). There are two kinds of firms, final goods and intermediate goods. Final goods firms produce two types of goods, namely, consumption goods and investment goods which are not internationally traded. On the other hand, intermediate goods firms produce goods which can be used for processing consumption and investment goods and these intermediate goods are also tradeable. We assume that these intermediate goods firms produce differentiated variety of goods and as a result each producer has some monopoly power of price setting. The nexus of producing firms is similar to Kollmann (2002) and Basu and Thoenissen (2011). There is a government in charge of fiscal spending. Government spending is in the form of final goods consumption and is financed by taxes and domestic borrowing. The Central Bank follows a forward looking Taylor type interest rate to respond to inflation and business cycle conditions.

2.2 Representative Household

There are continuum of agents in the home economy in unit interval. A fraction λ of consumers (with suffix 1) are forward looking and the remaining fraction $(1 - \lambda)$ are rule of thumb consumers (with suffix 2). Forward looking consumers maximize the following present value of its lifetime expected utility subject to standard flow budget constraints.

$$E_0 \sum_{t=0}^{\infty} \beta^t V[(C_t^1 - \gamma_c C_{t-1}^1), L_t^1] \quad (1)$$

where E_0 denotes the conditional expectation at date t , β is the intertemporal discount factor, with $0 < \beta < 1$. There is aggregate habit formation which means that the consumer receives utility from current consumption, C_t after adjusting for the previous period's aggregate level of consumption, C_{t-1} and suffers disutility from supplying labour, L_t . Utility function is additively separable in consumption and labour and specify as follows:

$$V(.) = \left[\frac{1}{1-\sigma_c} (C_t^1 - \gamma_c C_{t-1})^{1-\sigma_c} - \frac{1}{1+\sigma_l} (L_t^1)^{1+\sigma_l} \right] \quad (2)$$

where σ_c denotes the inverse of the elasticity of substitution in consumption and σ_l is inversely proportional to the Frisch labour supply elasticity.

Home residents trade two nominal riskless bonds of one period maturity denominated in the domestic and foreign currency respectively. Residents in both countries issue these bonds to finance their consumption expenditures. We follow Benigno (2009) by assuming that home bonds are only traded nationally while foreign residents allocate their wealth in foreign bonds denominated in the foreign currency. This asymmetry in the financial market structure is reflecting the stark nature of capital control facing a developing country like India. The international financial market is thus incomplete because only a riskless foreign currency deaminated bond is internationally traded. There is a transaction cost facing the home households when they take a position in the foreign bond market. As in Benigno (2009) this cost depends on the net foreign asset position of the home economy.

The forward looking household also purchases investment goods (X_t) at a price $P_{x,t}$ to undertake capital accumulation using the investment technology:

$$K_{t+1} = (1 - \delta)K_t + [1 - S(X_t/X_{t-1})]X_t \quad (3)$$

where δ is the rate of depreciation of the capital stock and $S(.)$ captures investment adjustment costs as proposed by Christiano et al. (2005). We make standard assumption that $S(1) = S'(1) = 0$ and $S''(1) = \varkappa > 0$. The implication is that adjustment cost disappears in the long run.,

The representative home consumer thus faces the following budget constraint:

$$P_t C_t^1 + P_{x,t} X_t + \frac{B_{H,t}}{(1 + i_t)} + \frac{\xi_t B_{F,t}}{(1 + i_t^*) \Theta \left(\frac{\xi_t B_{F,t}}{P_t} \right)} = W_t L_t + R_{k,t} K_t + B_{H,t-1} + \xi_t B_{F,t-1} + \Omega_t^d - T_t \quad (4)$$

where $B_{H,t}$ and $B_{F,t}$ are the individual's holdings of domestic and foreign nominal riskless bonds denominated in the local currency, i_t is the home country nominal interest rate, i_t^* is the foreign country nominal interest rate, ξ_t is the nominal exchange rate expressed as the price of one unit of foreign currency in terms of home currency, P_t is the consumer price level and W_t is the nominal wage. The representative home household supplies labour and rents capital to the domestic intermediate goods firms which explains the remaining wage and rental income terms, $W_t L_t$, $R_{k,t} K_t$ in the household's flow budget constraint. In addition, $\Omega_t^{d,j}$ is the profit income of the household from the domestic intermediate goods firms. Home agents own all domestic intermediate firms and the equity holding within these firms is evenly divided between domestic agents.³

The cost function $\Theta(\cdot)$ drives a wedge between the returns on foreign and home bonds. Benigno (2009) ascribes this cost to the existence of foreign-owned intermediaries in the foreign asset market who apply a spread over the risk-free rate of interest when borrowing or lending to home agents in foreign currency. The implication is that the home country borrows from the foreign country at a premium but lends at a discount. The spread between the borrowing and lending rates depends on the net foreign asset position of the home economy. Profits from this activity in the foreign asset market are distributed equally among foreign residents. In the steady state this spread is zero. The cost function $\Theta(\cdot)$ is unity only when the net foreign asset position is at its steady state level, i.e. $B_{F,t} = \bar{B}$, and is a differentiable decreasing function in the neighbourhood of \bar{B} .

Household's first order conditions are

$$C_t^1 : (C_t^1 - \gamma_c C_{t-1})^{-\sigma_c} - \lambda_t P_t = 0 \quad (5)$$

$$L_t^1 : -L_t^{1\sigma_L} + \lambda_t P_t (W_t/P_t) = 0 \quad (6)$$

$$K_{t+1} : -\mu_t + E_t \mu_{t+1} (1 - \delta) + E_t \lambda_{t+1} P_{t+1} (R_{kt+1}/P_{t+1}) = 0 \quad (7)$$

³Note that positive profit arises from the ownership of monopolistic intermediate goods firms only because retail firms are all competitive.

$$X_t^j : \mu_t [(1 - s(X_t/X_{t-1})) - s'(X_t/X_{t-1})(X_t/X_{t-1})] + E_t \mu_{t+1} s'(X_{t+1}/X_t)(X_{t+1}/X_t)^2 - \lambda_t P_t (P_{xt}/P_t) = 0 \quad (8)$$

$$B_{H,t+1}^j : -\lambda_t \cdot \frac{1}{1 + i_t} + E_t \lambda_{t+1} = 0 \quad (9)$$

$$B_{F,t+1} : \frac{-\xi_t \lambda_t}{(1 + i_t^*) \Theta \left(\frac{\xi_t B_{F,t}^j}{P_t} \right)} + E_t \xi_{t+1} \lambda_{t+1} = 0 \quad (10)$$

where λ_t and μ_t are the Lagrange multipliers associated with the nominal flow budget constraint (4) and the capital accumulation technology (3) respectively.

Next, note that the Tobin's q (the opportunity cost of investment in terms of foregoing consumption) is defined as:

$$q_t = \frac{\mu_t}{P_t \lambda_t}$$

Using this definition of q the Euler equation (8) can be rewritten as:

$$q_t [(1 - s(X_t/X_{t-1})) - s'(X_t/X_{t-1})(X_t/X_{t-1})] + E_t q_{t+1} s'(X_{t+1}/X_t)(X_{t+1}/X_t)^2 m_{t+1} = P_{xt}/P_t \quad (11)$$

where m_{t+1} is the stochastic discount factor equal to $\beta(C_{t+1}^1 - \gamma_c C_t)^{-\sigma_c} / (C_t^1 - \gamma_c C_{t-1})^{-\sigma_c}$ and equation (7) can be written as:

$$q_t = E_t q_{t+1} (1 - \delta) m_{t+1} + E_t m_{t+1} (R_{kt+1}/P_{t+1}) \quad (12)$$

As in Benigno (2009), all individuals belonging to the same country have the same level of initial wealth. This assumption, along with the fact that all individuals face the same labour demand and own an equal share of all firms, implies that within the same country all individuals face the same budget constraint. Thus they choose identical paths for consumption. For this reasons of symmetry, hereafter we drop the suffix j .

2.3 Rule-of-thumb Consumers

As in Gali et al. (2005), we bring limited asset market participation by introducing a fraction $(1 - \lambda)$ of rule-of-thumb households who do not have any access to asset markets and thus are not

forward looking. Their first order condition only satisfies the static efficiency condition as follows:

$$L_t^{2^{\sigma_L}} = (C_t^2 - \gamma_c C_{t-1})^{-\sigma_c} (W_t/P_t)$$

They also consume their current income and do not save or invest. In other words,

$$C_t^2 = \frac{W_t}{P_t} L_t^2$$

The aggregate consumption demand is given by:

$$C_t = \lambda C_t^1 + (1 - \lambda) C_t^2$$

The aggregate labour supply given by

$$L_t = \lambda L_t^1 + (1 - \lambda) L_t^2$$

2.4 Final Goods Producing Firms

2.4.1 Consumption Goods Sector

There are competitive distributors who package home and foreign intermediate consumption goods ($C_{H,t}$ and $C_{F,t}$) to deliver final consumption goods (C_t) to the household. While packaging these two goods, they use the following CES technology.

$$C_t = \left[v^{\frac{1}{\theta}} C_{H,t}^{\frac{\theta-1}{\theta}} + (1-v)^{\frac{1}{\theta}} C_{F,t}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \quad (13)$$

where θ is the elasticity of intra-temporal elasticity of substitution between home and foreign-produced consumption goods and v is the home bias in consumption.

Both home and foreign consumption goods consist of a continuum of intermediate goods in the unit interval based on the following CES technology:

$$C_{H,t} = \left[\int_0^1 C_{H,t}^{\frac{\varepsilon-1}{\varepsilon}}(i) di \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (14)$$

$$C_{F,t} = \left[\int_0^1 C_{F,t}^{\frac{\varepsilon-1}{\varepsilon}}(i) di \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (15)$$

Cost minimization by final consumption goods producers yields the following input demand functions for the home economy (similar conditions hold for foreign producers).

$$\begin{aligned} C_{H,t}(i) &= \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\varepsilon} v \left(\frac{P_{H,t}}{P_t} \right)^{-\theta} C_t \\ C_{F,t}(i) &= \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{-\varepsilon} (1-v) \left(\frac{P_{F,t}}{P_t} \right)^{-\theta} C_t \end{aligned} \quad (16)$$

The consumer price index (CPI) that corresponds to the previous demand function is defined as:

$$P_t = [vP_{H,t}^{1-\theta} + (1-v)P_{F,t}^{1-\theta}]^{1/(1-\theta)} \quad (17)$$

while

$$P_{H,t} = \left[\int_0^1 P_{H,t}^{1-\varepsilon}(i) di \right]^{\frac{1}{1-\varepsilon}} \quad (18)$$

and

$$P_{F,t} = \left[\int_0^1 P_{F,t}^{1-\varepsilon}(i) di \right]^{\frac{1}{1-\varepsilon}} \quad (19)$$

$P_{H,t}$ and $P_{F,t}$ will be determined by price setting behaviour of domestic intermediate goods firms and foreign owned intermediate goods importing firms which will be specified later.

2.4.2 Investment Goods Sector

Final investment goods (X_t) are produced by combining home and foreign-produced intermediate goods ($X_{H,t}$ and $X_{F,t}$) in an analogous manner:

$$X_t = Z_{x,t} \left[\varphi^{\frac{1}{\tau}} X_{H,t}^{\frac{\tau-1}{\tau}} + (1-\varphi)^{\frac{1}{\tau}} X_{F,t}^{\frac{\tau-1}{\tau}} \right]^{\frac{\tau}{\tau-1}} \quad (20)$$

where φ is the home bias in investment and τ is the elasticity of substitution between home and foreign intermediate inputs and $Z_{x,t}$ is investment specific technology shock (IST) and it appears

in the investment goods production function as a total factor productivity (TFP) term as in Basu and Thoenissen (2011).

$$X_{H,t} = \left[\int_0^1 X_{H,t}^{\frac{\varepsilon-1}{\varepsilon}}(i) di \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (21)$$

$$X_{F,t} = \left[\int_0^1 X_{F,t}^{\frac{\varepsilon-1}{\varepsilon}}(i) di \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (22)$$

Cost minimization by these investment goods firms yields the following demand functions:

$$X_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\varepsilon} \varphi \left(\frac{P_{H,t}}{P_{x,t}} \right)^{-\tau} X_t \quad (23)$$

$$X_{F,t}(i) = \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{-\varepsilon} (1 - \varphi) \left(\frac{P_{F,t}}{P_{x,t}} \right)^{-\tau} X_t \quad (24)$$

where the investment goods price index (or the producer price index, PPI) is given by:

$$P_{x,t} = \left[\varphi P_{H,t}^{1-\tau} + (1 - \varphi) P_{F,t}^{1-\tau} \right]^{1/(1-\tau)} \quad (25)$$

The PPI is a function of the price of home and foreign-produced intermediate goods prices. It differs from the CPI due to different substitution elasticities, different degrees of consumption and investment home biases.

2.4.3 Completing the Price Nexus

The price indices for consumption and investment goods are given by:

$$P_t = P_{H,t} \left[\nu + (1 - \nu) (P_{F,t}/P_{H,t})^{1-\theta} \right]^{1/(1-\theta)} \quad (26)$$

$$P_{xt} = P_{H,t} \left[\varphi + (1 - \varphi) (P_{F,t}/P_{H,t})^{1-\tau} \right]^{1/(1-\tau)} (1/Z_{xt})$$

Thus, the relative price of investment is:

$$\frac{P_{x,t}}{P_t} = \frac{\left[\varphi + (1 - \varphi) (P_{F,t}/P_{H,t})^{1-\tau} \right]^{1/(1-\tau)}}{\left[\nu + (1 - \nu) (P_{F,t}/P_{H,t})^{1-\theta} \right]^{1/(1-\theta)}} \cdot \frac{1}{Z_{xt}} \quad (27)$$

As in Basu and Thoenissen (2011), the terms of trade $P_{F,t}/P_{H,t}$ can create a wedge between the relative price of investment ($P_{x,t}/P_t$) and the IST shock, Z_{xt} .

2.5 Intermediate Goods Producing Firms

As in Kollmann (2002) intermediate goods firms produce tradeable intermediate goods which can be used for consumption and investment by both home and foreign countries. These firms rent capital and hire labour from home households using the following constant returns to scale production function:

$$Y_t(i) = A_t K_t^\alpha(i) L_t^{1-\alpha}(i) \quad (28)$$

where A_t is total factor productivity (TFP). Cost minimization means

$$\frac{K_t(i)}{L_t(i)} = (1-\alpha)\alpha^{-1} \frac{W_t}{R_{k,t}} \quad (29)$$

where W_t and $R_{k,t}$ are the nominal wage and nominal rental price plus depreciation cost. It is straightforward to verify that the nominal marginal cost is:

$$MC_t = \frac{1}{A_t} R_{k,t}^\alpha W_t^{1-\alpha} \alpha^{-\alpha} (1-\alpha)^{\alpha-1} \quad (30)$$

The real marginal cost (denoted as mc_t) looks symmetric as (30) and can be written as:

$$mc_t = \frac{1}{A_t} r_{k,t}^\alpha w_t^{1-\alpha} \alpha^{-\alpha} (1-\alpha)^{\alpha-1} \quad (31)$$

where $r_{k,t}$ and w_t are real rental price and real wage.

2.6 Home and Foreign Demands

The aggregate home and foreign demands for home tradeable intermediate goods are given by:

$$Y_{H,t} = C_{H,t} + X_{H,t} \quad (32)$$

$$Y_{H,t}^* = C_{H,t}^* + X_{H,t}^* \quad (33)$$

Using (14), (23), (32) and integrating across all firms and ignoring the price dispersion term as an approximation, the aggregate home demand for intermediate goods can be written more compactly as:

$$Y_{H,t} = v \left(\frac{P_{H,t}}{P_t} \right)^{-\theta} C_t + \varphi \left(\frac{P_{H,t}}{P_{x,t}} \right)^{-\tau} X_t$$

Based on the assumption that the home country charges the price of its exportables in terms of foreign currency after indexing it for foreign inflation, we get the aggregate foreign demand for home intermediate goods use (33):⁴

$$Y_{H,t}^* = \lambda_1 \nu^* \left(\frac{\xi_t P_{H,t}^*}{P_t} . r x_t^{-1} \right)^{-\theta^*} + \lambda_2 \varphi^* \left(\frac{\xi_t P_{H,t}^*}{P_t} . r x_t^{-1} \right)^{-\tau^*} \quad (34)$$

where $r x_t$ is the real exchange rate defined as $\xi_t P_t^* / P_t$. We normalize the aggregate foreign demand Y_t^* to unity, which means that λ_1 and λ_2 are fractions of foreign GDP devoted to consumption and investment respectively.⁵

2.7 Price setting Equations

Because intermediate goods firms produce differentiated goods, they are monopolistic price setters. Price setting is staggered as in Calvo (1983). These firms set $P_{H,t}$ after receiving a price signal that γ_p fraction of firms will keep the price unchanged in the next period. They also take the demand functions of their intermediate goods as given.

The profit of the home intermediate goods firms is given by:

$$\Omega_t^d(P_{H,t}, P_{H,t}^*) = [(P_{H,t}(i) Y_{H,t}(i) + P_{H,t}^*(i) Y_{H,t}^*(i) - \Psi(Y_{H,t}(i) + Y_{H,t}^*(i)))] \quad (35)$$

where $\Psi(\cdot)$ is the nominal cost of production.

⁴Such a pricing behaviour of exportables is validated by the widespread pricing to market behaviour.

⁵To see how one gets (34), use the fact that $\frac{P_{H,t}^*}{P_t^*} = \frac{\xi_t P_{H,t}^*}{P_t} . r x_t^{-1}$ and $\frac{P_{H,t}^*}{P_{x,t}^*} = \frac{\xi_t P_{H,t}^*}{P_t} . r x_t^{-1} . \frac{P_t^*}{P_{x,t}^*}$. Next note that $\frac{P_{x,t}^*}{P_t^*} = \frac{[\varphi^* + (1-\varphi^*)(P_{F,t}^*/P_{H,t}^*)^{1-\tau^*}]^{1/(1-\tau^*)}}{[\nu^* + (1-\nu^*)(P_{F,t}^*/P_{H,t}^*)^{1-\theta^*}]^{1/(1-\theta^*)}} \cdot \frac{1}{Z_{x,t}^*}$. In our calibration we assume that $\tau^* = \theta^*$ and $\nu^* = \varphi^*$ as the baseline, which means $\frac{P_{x,t}^*}{P_t^*} = \frac{1}{Z_{x,t}^*}$ where $Z_{x,t}^*$ is the foreign IST shock which we assume away by normalizing to unity.

The dynamics of prices across two segmented markets (assuming identical nominal friction) can be written as:

$$P_{H,t} = \left[\gamma_p (P_{H,t-1} \Pi)^{1-\varepsilon} + (1 - \gamma_p) \left(\tilde{P}_{H,t} \right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \quad (36)$$

$$P_{H,t}^* = \left[\gamma_p \left(P_{H,t-1}^* \Pi^* \right)^{1-\varepsilon^*} + (1 - \gamma_p) \left(\tilde{P}_{H,t}^* \right)^{1-\varepsilon^*} \right]^{\frac{1}{1-\varepsilon^*}} \quad (37)$$

where ‘ $\tilde{\cdot}$ ’ stands for the optimal price and Π and Π^* are steady state home and foreign inflation rates.

Home price is determined by the following price setting problem :

$$\tilde{P}_{H,t} = \arg \max_{\varrho_t} \sum_{k=0}^{\infty} \beta^k \gamma_p^k D_{t,t+k} E_t \left[\Pi^k \varrho_t \left(\frac{\Pi^k \varrho_t}{P_{H,t+k}} \right)^{-\varepsilon} Y_{H,t+k} - \Psi(Y_{t+k}) \right] \quad (38)$$

where $D_{t,t+k}$ is the inflation adjusted stochastic discount factor equal to $(V_{1t+k}/V_{1t}) \cdot (P_t/P_{t+k})$ with the subscript of $V(\cdot, \cdot)$ representing the partial derivative with respect to the first argument of the utility function in Eq. (2).

Since prices are non-stationary, we deflate the domestic price by CPI. By doing this, one can write the optimal price in a standard form as follows:

$$\frac{\tilde{P}_{H,t}}{P_t} = \frac{(\varepsilon/(\varepsilon - 1)) E_t \sum_{k=0}^{\infty} (\beta^k \gamma_p^k D_{t,t+k} m_{t+k} Y_{H,t+k})}{E_t \sum_{k=0}^{\infty} \beta^k \gamma_p^k D_{t,t+k} Y_{H,t+k}} \quad (39)$$

which can be written in the following recursive form at the steady state where Y_{Ht} is time invariant:⁶

$$\frac{\tilde{P}_{H,t}}{P_t} = \frac{\varepsilon}{\varepsilon - 1} \cdot F_t^{-1} m_{t+k} + (1 - F_t^{-1}) E_t \frac{\tilde{P}_{H,t+1}}{P_{t+1}} \quad (40)$$

where

$$F_t = Y_{H,t}^{-1} E_t \sum_{k=0}^{\infty} \beta^k \gamma_p^k D_{t,t+k} Y_{H,t+k} \Pi_{t+k} \quad (41)$$

The price setting problem for the export price is analogous to the domestic prices except that it takes account of the fact that the home country sets its export price in foreign currency indexing

⁶Details of the derivation of (40) are available from the authors upon request.

it against foreign steady state inflation rate Π^* as in Kollmann (2002). It is given by:⁷

$$\tilde{P}_{H,t}^* = \arg \max_{\varkappa_t} \sum_{k=0}^{\infty} \beta^k \gamma_p^k D_{t,t+k} E_t \left[\xi_{t+k} \Pi^{*k} \varkappa_t \left(\frac{\varkappa_t \Pi^{*k}}{P_{t+k}} \right)^{-\varepsilon^*} Y_{H,t+k}^* - \Psi(Y_{t+k}) \right] \quad (42)$$

The optimal export price can be written analogously as:⁸

$$\frac{\xi_t \tilde{P}_{H,t}^*}{P_t} = \frac{(\varepsilon^*/(\varepsilon^* - 1)) E_t \sum_{k=0}^{\infty} \beta^k \gamma_p^k D_{t,t+k} m c_{t+k} Y_{H,t+k}^* \Pi_{t+k}}{E_t \sum_{k=0}^{\infty} (\gamma_p \Pi^{*- \varepsilon^*})^k D_{t,t+k} Y_{H,t+k}^* \Pi_{t+k}} \quad (43)$$

which gives rise to the following recursive representation of the relative export price with respect to the home CPI:

$$\frac{\tilde{P}_{H,t}^* \xi_t}{P_t} = \frac{\varepsilon^*}{\varepsilon^* - 1} F_t^{*-1} m c_t + \Pi^{*\varepsilon^*} (1 - F_t^{*-1}) E_t \frac{\tilde{P}_{H,t+1}^* \xi_{t+1}}{P_{t+1}} \quad (44)$$

where

$$F_t^* = Y_{H,t}^{*-1} E_t \sum_{k=0}^{\infty} \beta^k \gamma_p^k \Pi^{*-k\varepsilon^*} D_{t,t+k} Y_{H,t+k}^* \Pi_{t+k} \quad (45)$$

Not surprisingly, the relative domestic and export prices (40) and (44) depend positively on the current and anticipated real marginal cost via the staggered price setting rules.

2.8 Fiscal Policy

The home government consumes G_t of final consumption goods and finances this by lump sum taxes T_t and borrowing. The government issues bonds which are domestically held. In other words, the government budget constraint is:

$$P_t G_t - T_t = \frac{B_{H,t+1}}{1 + i_t} - B_{H,t} \quad (46)$$

⁷In a world of law of one price (LOOP), the foreign terms of trade is identical to home terms of trade and thus the export price setting equation becomes redundant. However, we do not assume LOOP in our model as in Kollmann (2002).

⁸The details of the derivation of (44) are available upon request from the authors.

The government spending G_t is the single fiscal policy tool which is formulated as the following process:

$$\ln G_t - \ln \bar{G} = \rho_G(\ln G_{t-1} - \ln \bar{G}) + \xi_{Gt} \quad (47)$$

where \bar{G} is the steady state government spending, $\rho_G \in (0, 1)$ is the persistence of fiscal spending, ξ_{Gt} is the fiscal policy white noise shock.

2.9 Real Exchange Rate

The real exchange rate is defined as the ratio of foreign to home CPI ($\xi_t P_t^*/P_t$). It is straightforward to verify the following identity for the real exchange rate (call it RX_t):⁹

$$RX_t = \frac{P_{t-1}}{P_t} \cdot \frac{P_t^*}{P_{t-1}^*} \cdot \frac{\xi_t}{\xi_{t-1}} \cdot RX_{t-1}$$

Assuming that the foreign inflation rate is constant, the loglinear version of the real exchange rate process is given by:

$$\widehat{RX}_t = \frac{\widehat{\xi}_t}{\widehat{\xi}_{t-1}} - \frac{\widehat{P}_t}{\widehat{P}_{t-1}} + \widehat{RX}_{t-1} \quad (48)$$

Thus the real exchange rate fluctuates around its PPP level following the relationship (48).

2.10 Home Monetary Policy

The Central Bank (CB) sets an interest rate rule (i_t) and it auctions off $\{B_{H,t}\}$ sequence of bonds at that mandated interest rate to finance the government spending stream $\{G_t\}$. Any shortfall is financed by lump-sum taxation, $\{T_t\}$ which obeys the government budget constraint (47).

The interest rate sequence follows a standard Taylor rule in the short run and is specified as follows.¹⁰

$$\widehat{i}_t = \phi_i \widehat{i}_{t-1} + (1 - \phi_i) [\phi_\pi E_t \{\widehat{\pi}_{t+1}\} + \phi_y \widehat{y}_{H,t}] + \xi_t^m \quad (49)$$

where ‘ $\widehat{\cdot}$ ’ represents the proportional deviation from the steady state, ϕ_i is the interest rate smoothing parameter, ϕ_π and ϕ_y are the policy response to expected inflation $\widehat{\pi}_{t+1}$ and output gap, $\widehat{y}_{H,t}$.

⁹The first author is grateful to Yongdae Lee to point out this useful identity.

¹⁰We follow Kollmann (2002) in formulating the interest rate rule as a function of $\widehat{y}_{H,t}$ (which is the deviation of y_{Ht} from the steady state). $\widehat{y}_{H,t}$ is analogous to output gap in a standard new Keynesian model.

We assume that the home monetary authority is solely concerned about the domestic inflation and output fluctuations in designing its own monetary policy.¹¹

2.11 Market Equilibrium

The solution to our model satisfies the following market equilibrium conditions must hold for the home and foreign country:

1. Home-produced intermediate goods market clears:

$$Y_t = Y_{H,t} + Y_{H,t}^* \quad (50)$$

2. Foreign-produced intermediate goods market clears:

$$Y_t^* = Y_{F,t} + Y_{F,t}^* \quad (51)$$

3. Bond Market clears:

$$\frac{\xi_t B_{F,t}}{P_t(1+i_t^*)\Theta\left(\frac{\xi_t B_{F,t}}{P_t}\right)} - \frac{\xi_t B_{F,t-1}}{P_t} = \frac{\xi_t P_{H,t}^*}{P_t} Y_{H,t}^* - \frac{P_{F,t}}{P_t} Y_{F,t} \quad (52)$$

4. $\{B_{Ht}\}$ follows the government budget constraint (46).

Note that the first equality in (52) shows the current account balance. The right hand side is home country's net export.

¹¹One may debate whether during the QE phase, the RBI explicitly followed the lead given by the major player such as Federal Reserve or ECB in formulating its own monetary policy. There is no clear such evidence that it was the case. In fact the data (as seen Figure 2) suggest that the Indian Repo rate diverged from the US Federal Funds rate since 2009 which is contrary to such posited leader-follower relationship. We thus assume that the home Central Bank basically follows a traditional forward looking Taylor rule.

2.12 National Income Accounting

It is straightforward to verify that the Walras law holds for the aggregate economy. Aggregate the flow budget constraints of all home households to get:

$$\begin{aligned} P_t C_t + P_{x,t} X_t + \frac{B_{H,t+1}}{(1+i_t)} + \frac{\xi_t B_{F,t}}{(1+i_t^*) \Theta\left(\frac{\xi_t B_{F,t}}{P_t}\right)} \\ = B_{H,t} + \xi_t B_{F,t-1} + W_t L_t + R_{k,t} K_t + \Omega_t^d - T_t \end{aligned}$$

Then substitute the bond market clearing condition (52) to get:

$$P_t C_t + P_{x,t} X_t + \frac{B_{H,t+1}}{(1+i_t)} - B_{H,t} + P_{H,t}^* \xi_t Y_{H,t}^* - P_{F,t} Y_{F,t} = W_t L_t + R_{k,t} K_t + \Omega_t^d - T_t \quad (53)$$

However the aggregate profit is given by:

$$\Omega_t^d = P_{H,t} Y_t - W_t L_t - R_{k,t} K_t \quad (54)$$

which after plugging into (53) yields

$$P_t C_t + P_{x,t} X_t + \frac{B_{H,t+1}}{(1+i_t)} - B_{H,t} + P_{H,t}^* \xi_t Y_{H,t}^* - P_{F,t} (C_{F,t} + X_{F,t}) = P_{H,t} Y_t - T_t \quad (55)$$

Finally substitute the government budget constraint to get rid of the tax term yields

$$P_t C_t + P_{x,t} X_t + P_t G_t + P_{H,t}^* \xi_t Y_{H,t}^* - P_{F,t} Y_{F,t} = P_{H,t} Y_t \quad (56)$$

Note that $(P_{H,t}^* \xi_t Y_{H,t}^* - P_{F,t} Y_{F,t})$ is home country's net export. Thus we verify the national income identity.

2.13 Modified Uncovered Interest Parity Condition

From (9) and (10),

$$\frac{1+i_t}{1+i_t^*} = E_t \frac{\xi_{t+1}}{\xi_t} \cdot \Theta\left(\frac{\xi_t B_{F,t}}{P_t}\right) \quad (57)$$

The bond holding cost function $\Theta(\cdot)$ drives wedge between home and foreign bond returns.

3 Modelling Quantitative Easing

Motivated by a persistent decline in the US federal funds rate during the QE era, we model the quantitative easing shock as a negative shock in the foreign interest rate with a slow recovery. A positive eight quarter ahead "news" shock is added to the foreign interest rate to represent the "taper talk." ¹²In other words, the foreign interest is modelled as:

$$\widehat{i}_t^* = \phi_i^* \widehat{i}_{t-1}^* - (\xi_t^{*m} - \xi_{t-8}^{*m}) \quad (58)$$

where ϕ_i^* is the phasing out parameter and ξ_t^{*m} is a white noise. The baseline parameterization of the model is shown in Table 1. There are four additional shocks in the model namely, TFP (A_t), IST (Z_t^x), fiscal spending (G_t), and home monetary policy (i_t). Since the centre of attention in this paper is the QE shock, we set the serial correlation parameters for all the remaining shocks to zero. Most of the baseline parameters are close to the values chosen in Banerjee and Basu (2015). We assume a higher home bias in investment than consumption on par with Banerjee and Basu (2015). The rationale for choosing a low value for the nominal rigidity parameter γ_p in the context of India is also explained in Banerjee and Basu (2015). The steady state inflation rates for home and foreign countries are fixed at 3% to 2% respectively which means a steady state depreciation rate of 1% for the home currency.¹³ The phasing out parameter ϕ_i^* is fixed at 0.86 based on an AR(1) estimation of the historical annual federal funds rate for the period 1956-2012. The risk aversion parameter σ_c is fixed at 2 which is in line with the estimate of Levine and Pearlman(2011). There is no readily available estimate of the proportion of rule-of-thumb consumers ($1 - \lambda$) for the Indian economy. Gali et al. (2005) use $\lambda = 0.5$. Given the existence of a vast informal sector in India, we set a greater value of $1-\lambda$ equal to 0.7. Changing λ in this vicinity has nearly no effect on the impulse response analysis that we report later.

¹²An eight quarter lag is arbitrarily chosen assuming that the market foresees the tapering of QE about two years ahead. Changing this lag to four quarters makes no difference to the impulse response analysis except that the actual taper materializes after four quarters instead of eight quarters.

¹³Setting a higher steady state inflation rate for the home country does not change the impulse response properties of the model.

Table 1: Baseline Parameterization

β	σ_c	σ_L	γ_c	γ_p	ε	ε^*	θ	ν	φ	ν^*	φ^*	τ	α
0.98	2	0	0.6	0.22	6	6	2	0.7	0.8	0.8	0.8	2	0.3

Table 2: Baseline Parameterization (Contd)

δ	$S''(1)$	ϕ_i	ϕ_π	ϕ_y	ϕ_i^*	$\Theta'(\bar{b}_f).\bar{c}$	λ_1	λ_2	Π	Π^*
0.1	2.5	0.81	1.64	0.5	0.86	0.001	0.67	0.24	1.03	1.02

Figure 3 plots the impulse responses of the relevant macroeconomic aggregates followed by one standard deviation negative shock in the foreign interest rate from a steady state value. This decline in foreign interest rate is motivated by the sharp drop in the US federal funds rate from its baseline value of 5% since 2007 (Figure 2). Given the domestic interest rate, such a decline in foreign interest rate makes the home currency depreciate via the UIP condition (57). Since home producers of intermediate goods set the export price in foreign currency, the depreciation of home currency raises the optimal relative price of exportables ($\tilde{P}_{H,t}^* \xi_t / P_t$) in (44). Intermediate goods producers, therefore, experience a rise in export revenue from the sale of intermediate goods abroad. This encourages them to expand the intermediate goods output for the export market. The immediate effect of this output expansion is a rise in the real marginal cost mc_t in eq (44) which in turn boosts the optimal relative home price of tradeable ($\tilde{P}_{H,t} / P_t$) via the price setting rule (40). This rise in $\tilde{P}_{H,t} / P_t$ fuels domestic inflation via the price aggregator (36). The home Central Bank reacts to it by raising the nominal interest rate based on the Taylor rule (49). Thus home interest rate moves in the opposite direction to the change in the foreign rate which is consistent with the stylized facts reported earlier.

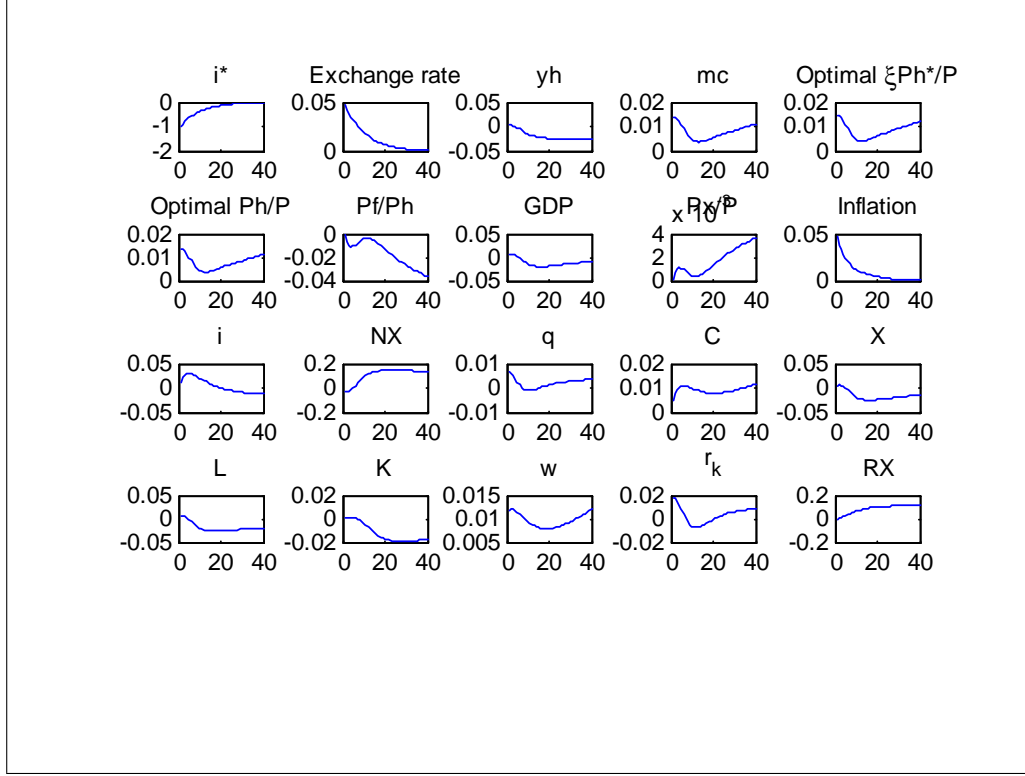


Figure 3: Effect of a QE Shock

Higher real marginal cost translates into a higher real wage and rental price of capital via (31). Agents respond to this by supply more labour and investing more in physical capital which raises the Tobin's q . Higher wage and rental income create positive income effect which boosts household consumption. The overall impact effect of a QE on GDP is positive which reflects the spurt in home intermediate goods production but it is rather small because of the decline in net export.

3.1 Effect of a QE Taper Talk

Figure 2 plots the impulse response of a "news" that QE will be phased out. We model this as an expected rise in foreign interest rate eight quarters ahead which means a positive shock to ξ_{t-8} . Market anticipates an appreciation of home currency which translates into a lower expected relative price of exportable via the price setting function. The real effect of such taper talk works opposite to the effect a negative QE shock discussed in the earlier section. Intermediate goods producers react to this news about QE phase out by cutting back tradeable intermediate goods

production (Y_{Ht}). This lowers the real marginal cost, mc and it then translates into a lower inflation immediately via the price aggregator. The CB lowers interest rate in response to low inflation via the Taylor rule before the exchange rate actually appreciates. The anticipation of appreciation of home currency becomes a reality after eight quarters via the uncovered interest parity condition. However, following this monetary appreciation episode, home currency depreciates again as foreign interest rate reverts to its mean.

Given that the nominal exchange rate is not altered for eight quarters, lower domestic inflation raises the real exchange rate (RX) which translates into a higher optimal export price ($\xi_t P_{Ht}^*/P_t$). This boosts the real marginal cost and it raises P_H/P . The terms of trade P_F/P_H moves in the opposite direction to P_H/P following the price aggregator (26). Higher relative price of home goods shows up as an increase in GDP (see eq. 56)). The current account shows swings in response to this news effect due to conflicting movement of different relative prices. Not surprisingly, the Tobin's q mimics the pattern of the real marginal cost. The rest of the effects are similar as before.

The bottom-line of this impulse responses to QE taper news is that there are sudden reversal in the behaviour of some key macroeconomic aggregates such as the nominal exchange rate, net export and Tobin's q due to the *expectations effect*. For example, the terms of trade initially declines but then as soon as the tapering is realized after eight quarters, it reverses its course. The same also happens for the CPI inflation. There is initial deflation and then inflation picks up its momentum. The financial market summarized by the Tobin's q shows similar reversal.. Taper talk thus possibly gives rise to more volatility in these key macroeconomic aggregates.¹⁴

¹⁴We use the term volatility in the sense of sudden change in the track. Evidently, we are not addressing issue of volatility spillover which requires serious modelling of the second order effects of QE shocks. This is beyond the scope of this paper.

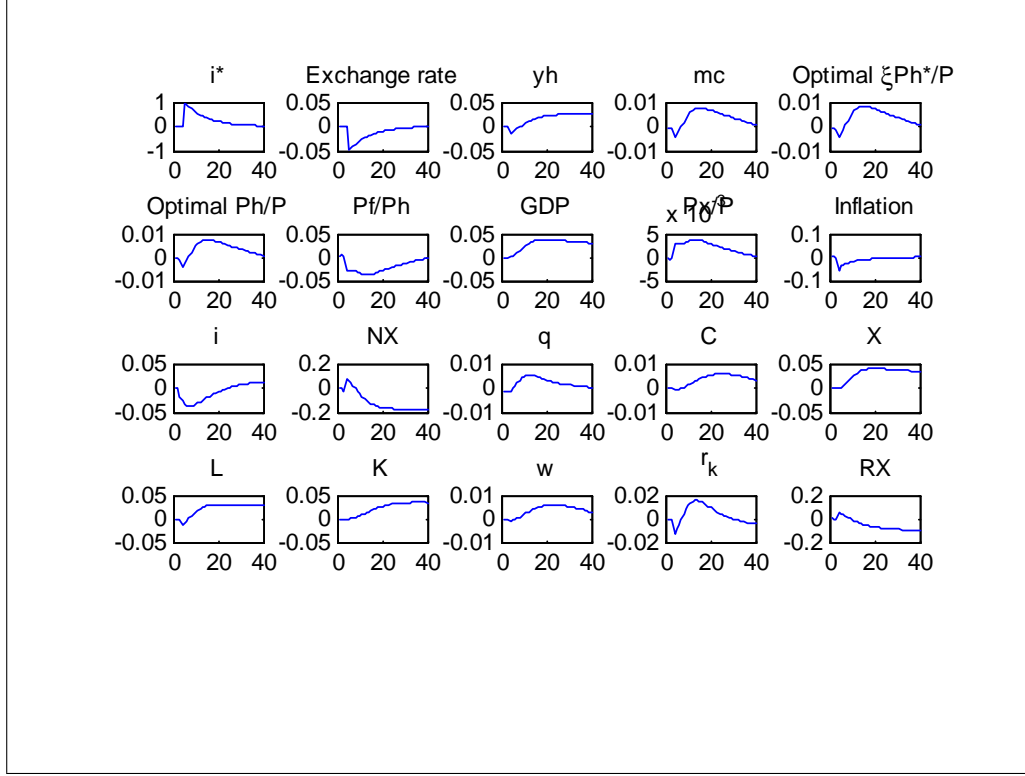


Figure 4: Effect of a QE Taper Talk

4 Conclusion

The aim of this paper is to develop a stylized DSGE framework to understand the effect of QE in a small open economy like India. This exercise is motivated by some broad stylized facts about the behaviour of key macroeconomic aggregates. What is novel in this paper is to highlight the effect of QE on the macroeconomy via the external terms of trade channel. Our model predicts that the QE innovation raises the real marginal cost of production in the home country because intermediate goods producers experience a favourable terms of trade effect and step up their production. This higher real marginal cost translates into inflation through the standard new Keynesian Phillips curve channel. The home Central Bank raises interest rate to respond to this inflation which explains the pervasive stylized fact that the home and foreign interest rates move in opposite directions after a few periods of QE innovation. We also model the QE taper talk as a "news" about future increase in foreign interest rate. Such a news effect creates market expectation about future appreciation of

home nominal interest rate which impacts the terms of trade positively as observed in the data. Our DSGE model predicts that such "news" would give rise to greater volatility in key macroeconomic aggregates in terms of a sudden change in their time paths.

The issue still remains whether the QE had any real macroeconomic effects on the Indian economy. Our impulse response analysis suggests that the effect of QE shock in the real GDP is rather minimal. It is still difficult to draw any definitive conclusion from the present model due to its highly stylized nature and the non-availability of high frequency data for real economic aggregates. In a companion paper (Banerjee and Basu, 2015) we find that the aggregate effect of foreign interest rate shock is minimal and the aggregate fluctuations are more governed by the investment specific technology shocks during the post liberalization period. Our present model also abstracts from many complications such as tax distortions, informal labour market, banking and credit market frictions. We also believe that banking frictions as in Gertler and Karadi (2012) are less important for India because of its highly regulated banking industry and this is why we assumed it away in our model. Credit market frictions in terms of a lending-borrowing spread and informal labour market can be introduced but it is unlikely to alter the main punchline of the paper.

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